



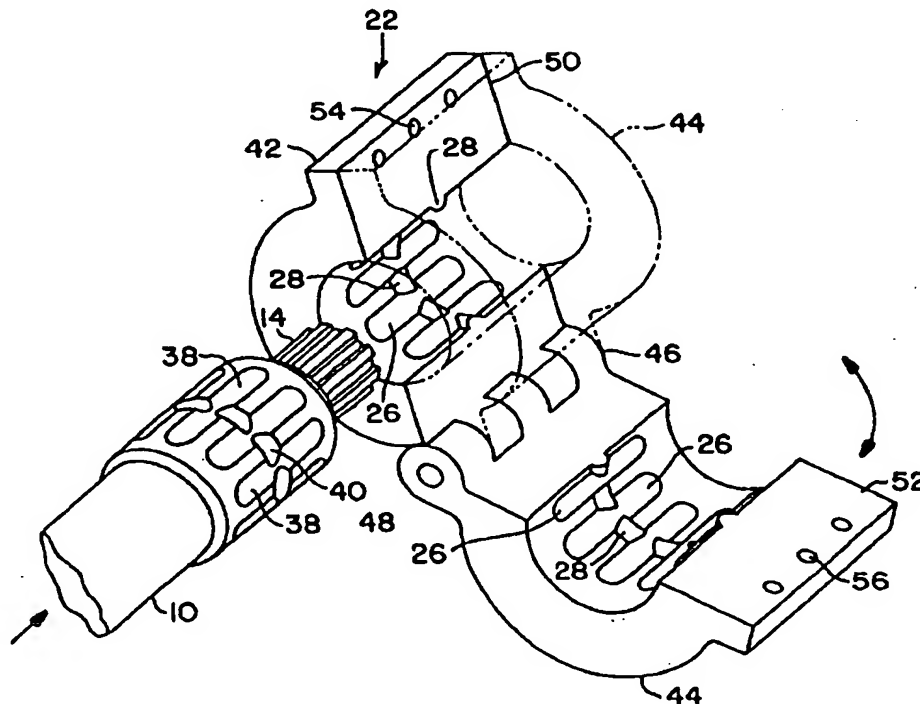
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(54) Title: METHOD AND FORMING DIE FOR FABRICATING TORQUE JOINTS

(57) Abstract

A method of fabricating or forming a tubular member (10) to produce a torque joint wherein the torque joint is formed using an external die arrangement (64) for electromagnetic concurrently forming longitudinal and circumferential or radial grooves in tubular members (10). For the concurrent formation of longitudinal and circumferential or radial grooves (76, 78), the external die (22) which encompasses the area of the components which is to be joined, has grooves (28) or recesses (26) machined in the circumferential inner surface of the die (22) such that upon the generating of an electromagnetic force by means of an internal coil (16) arranged within the area (20) which is to be deformed, the superimposed tubular member (10) is expanded outwardly so as to enter the recesses (26) or grooves (28) which are present in the inner encompassing surface of the external die (22). As a result, the interlocking groove structure or pattern formed in the tubular member (10) produces a torque joint.



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METHOD AND FORMING DIE FOR FABRICATING TORQUE JOINTS

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The present invention relates to a method for the fabricating or forming of tubular members of the torque tube type which may be utilized as torque joints for the drive shafts or steering connections of motor vehicles or in connection with articulating linkages for high-lift aircraft systems or for other various physical application where it is intended to react to torsional and axial loads which are ordinarily encountered in torque joints, steering linkages, drive shafts and the like. More particularly, pursuant to a further aspect of the invention, provision is made for a device which is in the form of a novel external die arrangement for electromagnetically concurrently forming longitudinal and circumferential or radial grooves in tubular members and interposed end fittings, particularly of the type which are adapted to react to torsional and axial loads encountered by torque joints and the like.

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In essence, it is a common procedure to form grooves in tubes and end fittings which are to be utilized in the fabrication of torque joints for drive shafts and the like in order to be able to react to torsional and axial loads which are encountered in the drive shafts. Heretofore, such grooves were generally produced by machining the tubular members in a labor-intensive and time-consuming manner, thereby rendering the entire process of their manufacture expensive and economically not viable.

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Pursuant to the more recent state of the
1 technology employed in the manufacture of so-called
conformal torque tube joints incorporating grooves in
both longitudinal and circumferential orientations in
order to produce a torque joint of interlockingly
5 formed tubular members, the end fitting and the
thereon or therein located tube were normally joined
together by concurrently forming torque-reacting
grooves over an internal shaped die member or mandrel
so as to eliminate the necessity for machining the
10 grooves in the end fitting.

For example, a method of fabricating a
torque joint incorporating longitudinal or axial
grooves and also providing for circumferentially
extending of radial grooves may be ascertained in
15 Arena U.S. Patent No. 4,513,488 which enable the
transmission of forces or loads in both longitudinal
or circumferential directions through the intermediary
of thin-walled and resultingly lightweight tubular
torque tubes. In that instance, an inner tube and an
20 outer tube are overlapped, a mandrel possessing
longitudinal and circumferential grooves inserted
therein, and an externally applied deformation force
compresses the tubular members into the grooves in the
mandrel, whereupon the mandrel or at least a portion
25 of the mandrel is extracted to then provide the formed
torque joint.

In Arena, et al. U.S. Patent No. 4,523,872,
there is disclosed a torque tube employing end members
interconnected by tubular member, wherein the end
30 members are provided with a male extension having

radially spaced, axially extending grooves with the
1 number of grooves, outer diameter of each end member,
groove width and groove length being in prescribed
proportions and ratios. The ends of the tubular
member are positioned over the male end member
5 extension and the tube walls conformed to the end
member and grooves through the external application of
electromagnetic energy so as to cause the tube walls
to be recessed or radially inwardly compressed into
the grooves.

10 Various methods and apparatus describing the
formation of grooves in tubular members in either
mechanical or electromagnetic modes, particularly such
as for the formation of torque joints and the like
suitable for diverse physical applications are
15 disclosed in Suh, et al. U.S. Patent No. 4,397,171;
Ohki U.S. Patent No. 4,598,451; Queyroix U.S. Patent
No. 3,810,372; Grob U.S. Patent No. 4,125,000;
Clements U.S. Patent No. 2,233,471; Savon U.S. Patent
No. 1,329,479; and Bright, et al. U.S. Patent No:
20 1,291,388.

Each and every one of the foregoing patents,
although disclosing the formation of grooves in
tubular members, for example, such as for the
formation of torque joints for drive shafts, aircraft
25 control linkages, and the like, disclose either
mechanical devices for compressing the material and/or
electromagnetic force-generating devices which are
normally externally applied so as to form longitudinal
and circumferential grooves, or devices generating

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internal electromagnetic forces to provide
1 longitudinally extending grooves in tubular members.

In accordance with the present invention, in clear contrast with the foregoing, and in a unique and novel manner of forming conformal torque joints from
5 interengaged tubular members and end fittings; in effect, for the concurrent formation of longitudinal and circumferential or radial grooves, an external die which encompasses the area of the components which is to be joined, has grooves or recesses machined in the
10 circumferential inner surface of the die such that upon the generating of an electromagnetic force by means of an internal coil arranged within the area which is to be deformed, the superimposed tubular member and end fitting material is expanded outwardly
15 so as to enter the recesses or grooves which are present in the inner encompassing surface of the external die. As a result, the interlocking groove structure or pattern formed in the tubular member and end fitting produces a torque joint which is adapted
20 to react to both axial and torsional forces and loads imposed thereon.

The formation of the conformal torque tubes or joints with both axially or longitudinally extending grooves and also circumferential or radial
25 grooves enables the reaction to encountered torsional and axial loads. Furthermore, through the expansive deformation of the material of the tubes or tubular members, in contrast with compressive deformation, there is a reduction in axial stress concentrations
30 which are normally encountered during the compression

of the material, while the expansion of the material
1 is also preferred in order to increase the moments of
inertia and the torque loading capabilities of such
torque joints. Moreover, the utilization of an
internal coil to generate the electromagnetic forces
5 rather than an external coil and internal mandrel,
causes the coil to be more stable so as not to tend to
degrade with repeated use as is the case with external
coils.

The formation of the conformal torque joints
10 or tubular members of the type described herein
through the inventive forming method facilitates their
utilization over a wide range of applications; i.e.,
in mechanical systems in which it is desired to
transmit driving forces or loads; for example, such as
15 in automotive drag links or steering arrangements, or
aircraft control, as well as for drive shafts of
automobiles. The torque joints may also be utilized
for the transmission of loads in structures located in
mechanisms for positioning and controlling airflow
20 surfaces of aircraft or the like.

Accordingly, in order to provide a method
for the formation of a conformal torque joint
incorporating both axial and circumferential or radial
grooves which are in a predetermined spaced
25 relationship relative to each other, the present
invention contemplates the provision of an external
die which may be of a construction having hinged
cooperating die portions to enable the pivotable
opening and closing thereof, and in which raised
30 ridges are formed in the internal cylindrical surface

of the external die, which extend in both axial and
1 circumferential directions, so that upon the closing
and latching of the external die about the tubular
members which are to form a torque joint, and the
energizing of an internal coil arranged within the
5 tubular members so as to generate an electromagnetic
force in this area within the external die, the
material of the tubular members will be expanded so as
to conformingly engage the surface portions of the
inner cylindrical wall structure of the external die,
10 thereby producing a composite pattern or arrangement
of outwardly displaced tubular surfaces having
inwardly directed axial and circumferential or radial
grooves formed in the tube members which are reactive
to both axial and torsional forces which may be
15 applied to the tube members of the resultingly formed
torque joint.

Alternatively, rather than the internal
cylindrical surface of the external die being provided
with raised ridges so as to form inwardly depending
20 grooves in the tubular members producing the torque
joint, it is provided with axially extending and
circumferentially spaced recesses and at least one
transverse or radial recess at a predetermined axial
location relative to the axial recesses, whereby upon
25 the generation of an electromagnetic force internally
of the tubular members the latter have the diameters
deformed thereof so as to incorporate outwardly
projecting axial and radial ridges rather than the
inwardly depending grooves.

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Still further, the internal cylindrical
1 surface of the external die may have an inwardly
extending annular flange or shoulder formed at one end
thereof so as to facilitate an accurate axial
positioning or insertion of the tubular members
5 whereby, upon outward deformation or expansion of the
tubular members, as described hereinabove, the end of
the axial length thereof located within the annular
flange of the die will have an annular configuration
forming a stepped-down end of smaller diameter
10 adjoining an end fitting of the torque joint.

The external die of the present invention
may comprise a pair of die halves of essentially
complementary configuration which are hingedly
interconnected so as to be pivotable about an axial or
15 longitudinal center plane or hinge line and which,
when closed into an operative position about the
tubular member and/or end fitting, has the die halves
latched together through suitable interengaging bolts
or pins extending through locking apertures, or
20 fastened together by suitable releasable clamping
devices, as is known in the technology.

The internal cylindrical or circumferential
surface of the external die halves may be provided
with suitably machined axial grooves, and one or more
25 circumferentially or radially extending grooves, or
may consist of raised ridges rather than grooves,
whereby the outer tubular member, which may have
another tubular member or end fitting inserted therein
or positioned thereon to form the conformal tube joint
30 is essentially of the same diameter as the cylindrical

grooved surface of the external die. Upon the
1 application of a suitable electromagnetic force or
current to an internal coil positioned within the
tubular members in the region located within the
confines of the die, the material of the tubular
5 members will expand so as to fill the spaces or lands
between the ridges or expanded into the grooves,
thereby forming the axial and circumferential grooves
in the conformed tubular members and producing a
torque joint which is able to react to both
10 longitudinal and torsional loads or forces.

Accordingly, the present invention provides
a method for forming axial and radial grooves in a
conformal tubular torque joint through the application
of an internal electromagnetic force expanding the
15 tube into grooves or spaced between ridges in the
internal encompassing cylindrical surface of an
external die structure.

The present invention further provides a
novel method of forming conformal torque joints and
20 grooved tubular members whereby at least a decreased
diameter end structure is produced adjacent one of the
ends of axial grooves formed in the torque joint.

Still further, the present invention
provides an external die having an internal
25 cylindrical surface encompassing tubular members and
incorporating axial and circumferential grooves or
raised ridges enabling expansion of the tubular
members through the application of an internal
electromagnetic force so as to form a conformal torque
30 joint having axial and radial grooves therein.

Still even further, the present invention
1 provides an external die for the formation of torque
joints incorporating both axial and circumferential
grooves through the application of an internal
electromagnetic force, whereby the external die is of
5 split and hingedly connected construction enabling the
rapid closure thereof and formation of the torque
joint, and facilitating the subsequent opening of the
die to enable removal of the torque joint.

Reference may now be had to the following
10 detailed description of preferred embodiments of the
invention, taken in conjunction with the accompanying
drawings; in which:

Figure 1 illustrates a generally schematic
longitudinal sectional view of a tubular member and
15 end fitting arranged to be formed into a torque joint
through the inventive external die structure;

Figure 2 illustrates the tubular member and
end fitting of Figure 1 shown in their deformed
position to constitute a torque joint produced
20 pursuant to the invention;

Figure 3 illustrates an exploded perspective
view of the formed torque joint and the external
forming die axially displaced for producing the torque
joint shown in an opened condition; and

25 Figure 4 illustrates, in a view similar to
Figure 3, a second embodiment of a torque joint and of
a forming die for producing a torque joint.

Referring in particular to Figures 1 and 2
of the drawings, shown therein are a pair of tubular
30 members 10, 12, each preferably consisting of aluminum

or other light-weight metal in order to be able to
1 form a light-weight torque joint, in which a first of
the tubular members 10 has the second tubular member
12 inserted therein in close slidable engagement, or
alternatively adapted to extend thereover, and with
5 the second tubular member 12 shown as having a splined
end 14 for providing a fitting connection with a
suitable drive arrangement or the like structure (not
shown). In lieu of the splined end 14, the second
tubular member 12 may be an end fitting which
10 possesses a clevis-type or bifurcated structure (not
shown) for forming a linkage connection, such as for
an automobile steering control system or for an
aircraft actuating linkage system for controlling
airfoil flow surfaces and the like, although other
15 numerous physical applications lend themselves to the
present invention in widely diverse industries
requiring the use of torque joints.

As shown in Figure 1, a suitable electrical
coil member 16 is adapted to be inserted into the
20 superimposed tubular members 10, 12 and connected to a
source of electrical current to provide for the
generating of an electromagnetic force. Encompassing
the outer circumference of the assembled tubular
members 10, 12 within the region 20 is an annular die
25 22. The annular die 22 has an inner cylindrical
surface 24 provided with radially inwardly protruding
circumferentially spaced raised axial ridges 26 and at
least one circumferential ridge 28 whose apices
contact the outer circumferential surface 30 of the
30 outer one of the tubular members 10, 12. This, in

essence, provides for an annular space 32 between the
1 inner cylindrical surface 24 of the die 22 and the
outer circumferential surface 30. Upon the
application of an electromagnetic force to the tubular
members 10, 12 by means of the electrical coil member
5 16, this will expand and deform the tubular members
10, 12 conjointly radially outwardly. The lands or
surface portions of the cylindrical die surface 24
intermediate the inwardly depending raised ridges 26,
28, and which initially forms the annular space 32
10 about the outer surface 30 of the tubular members 10,
12, has the tubular members deformed therein so as to
produce radially inwardly extending axial and
circumferential grooves 38, 40 conjointly in the
tubular members 10, 12 interlocking in nature and
15 which will form a fixed connection between the tubular
members in the form of a torque joint reactively
secured against encountered rotational and axial
torsional forces, as also illustrated in Figure 3.

In essence, as shown in perspective
20 representation in Figure 3 of the drawings, the
diameters of the superimposed tubular member portions
within the die 22 defined by the region 20 are
expanded to the cylindrical surface 24 of the inside
of the external die 22, whereby the circumferentially
25 spaced axial grooves 38 and the at least one radial
groove 40 in the tubular members 10, 12 extend
radially inwardly from the expanded surfaces thereof.

As shown in Figure 3, the external die 22,
which is of a heavy or solid metallic or of a
30 composite or dense plastic material construction, may

consist of a plurality of pivotably hinged sections
1 adapted to form an openable and closable die
structure; for example, consisting of two, three or an
even larger number of hinged die sections. In this
particular embodiment, as illustrated in the drawing,
5 at least two mating semi-circular halves 42, 44 which
are pivotally joined along one edge 46 by a suitable
hinge structure 48, and in which mating flange
structures 50, 52 at the opposite ends of the die
halves include either mutually aligning apertures 54,
10 56 facilitating the passage therethrough of locking
bolts in the closed position of the die, or any other
suitable clamping device attachable thereto for
latching the die into its closed operative structure,
as shown by the phantom lines, extending about the
15 tubular members 10, 12, as illustrated in Figures 1
and 2 of the drawings. Thereafter, upon the
implementation of the electromagnetic force by means
of the internal coil member 16 which is inserted into
the superimposed tubular members 10, 12 within the
20 region 20 of the encompassing die 22, the material of
the outwardly expanding deformed tubular member
extends into conformed contact with the inner surface
of die 22 and fills the interspaces or lands between
the radially inwardly extending ridges 26, 28 on the
25 die surface 24 so as to form the plurality of
circumferentially spaced axially extending grooves 38
and the at least one radially extending groove 40 in
the conjointly deformed tubular members 10, 12.

Although as illustrated in the drawings, in
30 which there has been shown only a single annular or

radial groove 40 located approximately in the middle
1 of the axial length of the longitudinal axial grooves
38, it is possible within the inventive concept to
provide one or more of such radial grooves 40 axially
spaced at suitable locations within region 20 along
5 the tubular members 10, 12, as may be desired for a
specific application.

Upon completion of the expansion or forming
process, the external die 22 is opened by the die
halves 42, 44 being swung apart at the hinge structure
10 48 so as to enable removal of the formed torque joint
and facilitating positioning a new set of superimposed
tubular members 10, 12 therein, inserting internal
coil member 16 and repeating the cycle, as previously
described in order to form a torque joint.

15 With respect to the embodiment of Figure 4
of the drawings in which similar or identical elements
are identified by the same reference numerals as in
Figure 3, in that instance one edge 60 of the inner
cylindrical surface 62 of the external die 64 is
20 optionally provided with an annular inwardly extending
flange or shoulder 66 of smaller diameter so as to
control the extent to which the tubular members 10, 12
are axially inserted therein, and whereby upon the
application of the electromagnetic force through the
25 internal coil member 16, as in the previous
embodiment, not only will there be formed the axial or
longitudinal grooves and radial groove to produce the
torque joint, but concurrently a smaller diameter
annulus 68 adjacent the fluted or splined end 14 of

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the one of the tube elements 12 which projects from
1 the external forming die 64.

Moreover, as illustrated in this particular
embodiment, rather than being provided with radially
inwardly extending ridges 26, 28 in the inner
5 cylindrical die surface as in Figure 3, which produces
radially inwardly extending axial and radial grooves
in the tubular members 10, 12 of the torque joint, in
this embodiment of Figure 4, the surface 62 of the
external die 64 is provided with or has machined
10 therein circumferentially spaced axial recesses 70 and
at least one radial recess 72 so that upon the
generating of the electromagnetic force by means of
the coil member 16 arranged within the tubular members
10, 12, the basic diameters of the tubular members 10,
15 12 will remain essentially undeformed; however,
portions thereof will expand or be deformed radially
outwardly into the recesses 70, 72 in the cylindrical
surface 62 of the external die 64, thereby forming
conjointly raised axial and radial ridges 76, 78 in
20 the tubular members 10, 12 producing the torque joint.
As in the previous embodiment, the number of axial
ridges formed is arbitrary and selected in accordance
with the particular physical application intended for
the torque joint, whereas there may also be provided
25 one or more radial ridges spaced along the axial
length of the axial ridges, as desired.

Additionally, although in Figure 4 of the
drawings the recesses 70, 72 which are formed in the
die surface 62 extend radially outwardly, these may be
30 formed to extend radially inwardly in the form of

1 raised surface portions or ridge elements as in the
external die 22 shown in Figure 3 of the drawings, so
as to form radially inwardly depending grooves in the
tubular members rather than radially outwardly
projecting ridges.

5 As in the previous embodiment, in this
instance the external die 64 is similarly formed of at
least two die halves 76, 78 or more hinged die
sections as necessary to prevent interlocking of the
formed tube with the die in the closed position of the
10 latter, after the tube and end fitting material has
been formed into the die. The die halves, or die
sections as required, are adapted to be interconnected
by means of a suitable pivot or hinge structure 80 and
locked together by means of suitable bolts extending
15 through aligned apertures 86, 88 formed in a mating
flange structure 82, 84 on the opposite ends of the
die halves. Alternatively, any type of suitable
clamping arrangement may be employed to maintain the
die halves in a closed latched position during the
20 forming of the torque joint.

While there has been shown and described
what are considered to be preferred embodiments of the
invention, it will, of course, be understood that
various modifications and changes in form or detail
25 could readily be made without departing from the
spirit of the invention. It is, therefore, intended
that the invention be not limited to the exact form
and detail herein shown and described, nor to anything
less than the whole of the invention herein disclosed
30 as hereinafter claimed.

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WHAT IS CLAIMED IS:

- 1 1. A method of fabricating a torque joint
between two tubular members having one end of one
tubular member inserted into an end of the other
tubular member to provide an overlapping region
5 between the tubular members; comprising the steps of:
 (a) encompassing the overlapping region of
said tubular members with an annular die having an
inner cylindrical surface facing the outer surface of
said overlapping region, said inner surface of said
10 annular die having a plurality of circumferentially
spaced axially extending ridges and at least one
radial ridge extending about said inner surface, said
ridges projecting radially inwardly so as to contact
the outer circumferential surface of said tubular
15 members, and said inner surface of said die defining
an annular space with the outer circumferential
surface of said tubular members;
 (b) inserting coil means connected to a
source of electrical energy into said tubular members
20 so as to extend into said overlapping region within
the confines of said annular die; and
 (c) imparting an electromagnetic force to
the interior of said tubular members in said
overlapping region by said coil means so as to
25 generate a deformation force expanding said tubular
members radially outwardly within said overlapping
region so as to impress said pattern of ridges on said
inner die surface onto said tubular members to produce
a corresponding pattern of axial and radial grooves
30 therein forming said torque joint.

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2. A method as claimed in Claim 1, wherein
1 said tubular members are expanded within said
overlapping region so as to assume an outer diameter
in conformance with the inner cylindrical surface of
said annular die.

5 3. A method as claimed in Claim 1, wherein
said annular die includes an annular inwardly
extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
10 forming a reduced diameter area on said tubular
members adjacent the grooves formed therein upon
expansion of said tubular members responsive to said
electromagnetic force.

4. A method as claimed in Claim 1, wherein
15 said annular die comprises a plurality of mating die
sections hingedly interconnected to enable insertion
of said tubular members and extraction thereof in the
open position of said die sections, and implementation
of deformation of said tubular members in the closed
20 position of said die sections.

5. A method as claimed in Claim 1, wherein
a plurality of said radial grooves are formed in said
tubular members spaced along the axial extent of the
formed axial grooves so as to provide a predetermined
25 pattern of grooves reacting to axial and torsional
loads imparted to the formed torque joint.

6. A method as claimed in Claim 1, wherein
at least one of said tubular members comprises an end
fitting for a torque joint.

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7. A method as claimed in Claim 1, wherein
1 said coil means comprises an electromagnetic coil
member insertable into said tubular members into close
conformance with the internal diameter of said tubular
member within said overlapping region.

5 8. A method of fabricating a torque joint
between two tubular members having one end of one
tubular member inserted into an end of the other
tubular member to provide an overlapping region
between the tubular members; comprising the steps of:

10 (a) encompassing the overlapping region of
said tubular members with an annular die having an
inner cylindrical surface facing the outer surface of
said overlapping region, said inner surface of said
annular die having a plurality of circumferentially
15 spaced axially extending recesses and at least one
radial recess extending about said inner surface, said
recesses extending radially outwardly so as to enable
said inner surface to contact the outer
circumferential surface of said tubular members;

20 (b) inserting coil means connected to a
source of electrical energy into said tubular members
so as to extend into said overlapping region within
the confines of said annular die; and

(c) imparting an electromagnetic force to
25 the interior of said tubular members in said
overlapping region by said coil means so as to
generate a deformation force expanding said tubular
members radially outwardly within said overlapping
region so as to impress said pattern of recesses on
30 said inner die surface onto said tubular members to

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produce a corresponding pattern of axial and radial
1 outwardly expanded grooves therein forming said torque
joint.

9. A method as claimed in Claim 8, wherein
said tubular members are expanded within said
5 overlapping region so as to assume an outer diameter
in conformance with the configuration of the inner
cylindrical surface of said annular die.

10. A method as claimed in Claim 8, wherein
said annular die includes an annular inwardly
10 extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
forming a reduced diameter area on said tubular
members adjacent the grooves formed therein upon
15 deformation of said tubular members responsive to said
electromagnetic force.

11. A method as claimed in Claim 8, wherein
said annular die comprises a plurality of mating die
sections hingedly interconnected to enable insertion
20 of said tubular members and extraction thereof in the
open position of said die sections, and implementation
of deformation of said tubular members in the closed
position of said die sections.

12. A method as claimed in Claim 8, wherein
25 a plurality of said radial grooves are formed in said
tubular members spaced along the axial extent of the
formed axial grooves so as to provide a predetermined
pattern of grooves reacting to axial and torsional
loads imparted to the formed torque joint.

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13. A method as claimed in Claim 8, wherein
1 at least one of said tubular members comprises an end
fitting for a torque joint.

14. A method as claimed in Claim 8, wherein
said coil means comprises an electromagnetic coil
5 member insertable into said tubular members into close
conformance with the internal diameter of said tubular
member within said overlapping region.

15. A die structure for fabricating a
torque joint between two tubular members having one
10 end of one tubular member inserted into an end of the
other tubular member to provide an overlapping region
between the tubular members; comprising:

(a) said die structure encompassing the
overlapping region of said tubular members including
15 an annular die having an inner cylindrical surface
facing the outer surface of said overlapping region,
said inner surface of said annular die having a
plurality of circumferentially spaced axially
extending ridges and at least one radial ridge
20 extending about said inner surface, said ridges
projecting radially inwardly so as to contact the
outer circumferential surface of said tubular members,
and said inner surface of said die defining an annular
space with the outer circumferential surface of said
25 tubular members;

(b) coil means connected to a source of
electrical energy being inserted into said tubular
members so as to extend into said overlapping region
within the confines of said annular die; and

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(c) said coil means imparting an
1 electromagnetic force to the interior of said tubular
members in said overlapping region so as to generate a
deformation force expanding said tubular members
radially outwardly within said overlapping region so
5 as to impress said pattern of ridges on said inner die
surface onto said tubular members to produce a
corresponding pattern of axial and radial grooves
therein forming said torque joint.

16. A die structure as claimed in Claim 15,
10 wherein said tubular members are expanded within said
overlapping region so as to assume an outer diameter
in conformance with the inner cylindrical surface of
said annular die.

17. A die structure as claimed in Claim 15,
15 wherein said annular die includes an annular inwardly
extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
forming a reduced diameter area on said tubular
20 members adjacent the grooves formed therein upon
expansion of said tubular members responsive to said
electromagnetic force.

18. A die structure as claimed in Claim 15,
wherein said annular die comprises a plurality of
25 mating die sections hingedly interconnected to enable
insertion of said tubular members and extraction
thereof in the open position of said die sections, and
implementation of deformation of said tubular members
in the closed position of said die sections.

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19. A die structure as claimed in Claim 15,
1 wherein a plurality of said radial grooves are formed
in said tubular members spaced along the axial extent
of the formed axial grooves so as to provide a
predetermined pattern of grooves reacting to axial and
5 torsional loads imparted to the formed torque joint.

20. A die structure as claimed in Claim 15,
wherein at least one of said tubular members comprises
an end fitting for a torque joint.

21. A die structure as claimed in Claim 15,
10 wherein said coil means comprises an electromagnetic
coil member insertable into said tubular members into
close conformance with the internal diameter of said
tubular member within said overlapping region.

22. A die structure for fabricating a
15 torque joint between two tubular members having one
end of one tubular member inserted into an end of the
other tubular member to provide an overlapping region
between the tubular members; comprising:

(a) said die structure encompassing the
20 overlapping region of said tubular members including
an annular die having an inner cylindrical surface
facing the outer surface of said overlapping region,
said inner surface of said annular die having a
plurality of circumferentially spaced axially
25 extending recesses and at least one radial recess
extending about said inner surface, said recesses
extending radially outwardly so as to enable said
inner surface to contact the outer circumferential
surface of said tubular members;

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(b) coil means connected to a source of
1 electrical energy being inserted into said tubular
members so as to extend into said overlapping region
within the confines of said annular die; and

(c) said coil means imparting an
5 electromagnetic force to the interior of said tubular
members in said overlapping region so as to generate a
deformation force expanding said tubular members
radially outwardly within said overlapping region so
as to impress said pattern of recesses on said inner
10 die surface onto said tubular members to produce a
corresponding pattern of axial and radial outwardly
expanded grooves therein forming said torque joint.

23. A die structure as claimed in Claim 22,
wherein said tubular members are expanded within said
15 overlapping region so as to assume an outer diameter
in conformance with the configuration of the inner
cylindrical surface of said annular die.

24. A die structure as claimed in Claim 22,
wherein said annular die includes an annular inwardly
20 extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
forming a reduced diameter area on said tubular
members adjacent the grooves formed therein upon
25 deformation of said tubular members responsive to said
electromagnetic force.

25. A die structure as claimed in Claim 22,
wherein said annular die comprises a plurality of
mating die sections hingedly interconnected to enable
30 insertion of said tubular members and extraction

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thereof in the open position of said die sections, and
1 implementation of deformation of said tubular members
in the closed position of said die sections.

26. A die structure as claimed in Claim 22,
wherein a plurality of said radial grooves are formed
5 in said tubular members spaced along the axial extent
of the formed axial grooves so as to provide a
predetermined pattern of grooves reacting to axial and
torsional loads imparted to the formed torque joint.

27. A die structure as claimed in Claim 22,
10 wherein at least one of said tubular members comprises
an end fitting for a torque joint.

28. A die structure as claimed in Claim 22,
wherein said coil means comprises an electromagnetic
coil member insertable into said tubular members into
15 close conformance with the internal diameter of said
tubular member within said overlapping region.

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AMENDED CLAIMS

[received by the International Bureau on 28 October 1997 (28.10.97);
original claims 1 - 28 replaced by new claims
1 - 24 (9 pages)]

1. A method of fabricating a torque joint
between two tubular members having one end of one
tubular member inserted into an end of the other
tubular member to provide an overlapping region
between the tubular members; comprising the steps of:
- (a) encompassing the overlapping region of
said tubular members with an annular die having an
inner cylindrical surface facing the outer surface of
said overlapping region, said annular die comprising a
plurality of mating die sections hingedly
interconnected to enable insertion of said tubular
members and extraction thereof in the open position of
said die sections, said inner surface of said annular
die having a plurality of circumferentially spaced
axially extending ridges and at least one radial ridge
extending about said inner surface, said ridges
projecting radially inwardly and contacting the outer
circumferential surface of said tubular members upon
closing of said mating die sections, and said inner
surface of said die defining an annular space with the
outer circumferential surface of said tubular members;
- (b) inserting an electrical coil member
which is connected to a source of electrical energy
into said tubular members so as to extend into said
overlapping region within the confines of said annular
die;
- (c) applying an electrical current to said
coil member by said source of electrical energy so as
to impart an electromagnetic force to the interior of
said tubular members in said overlapping region by
said coil member to generate a deformation force

AMENDED SHEET (ARTICLE 19)

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1 expanding said tubular members radially outwardly
within said overlapping region so as to impress said
pattern of ridges on said inner die surface onto said
tubular members to produce a corresponding pattern of
5 axial and radial grooves therein forming said torque
joint; and

(d) opening the hingedly interconnected
mating die sections upon completion of the formation
of said grooves so as to facilitate extraction of said
10 torque joint from said annular die.

2. A method as claimed in Claim 1, wherein
said tubular members are expanded within said
overlapping region to an outer diameter of a size
substantially that of the diameter of the inner
15 cylindrical surface of said annular die.

3. A method as claimed in Claim 1, wherein
said annular die includes an annular inwardly
extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
20 insertion of said tubular members into said die and
forming a reduced diameter area on said tubular
members adjacent the grooves formed therein upon
expansion of said tubular members responsive to said
electromagnetic force.

25 4. A method as claimed in Claim 1, wherein
a plurality of said radial grooves are formed in said
tubular members spaced along the length of the formed
axial grooves so as to provide a predetermined pattern
of grooves reacting to axial and torsional loads
30 imparted to the formed torque joint.

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1 5. A method as claimed in Claim 1, wherein
at least one of said tubular members comprises an end
fitting for a torque joint.

5 6. A method as claimed in Claim 1, wherein
said electromagnetic coil member insertable into said
tubular members has an outer diameter of substantially
the size of the internal diameter of said tubular
member within said overlapping region.

10 7. A method of fabricating a torque joint
between two tubular members having one end of one
tubular member inserted into an end of the other
tubular member to provide an overlapping region
between the tubular members; comprising the steps of:

15 (a) encompassing the overlapping region of
said tubular members with an annular die having an
inner cylindrical surface facing the outer surface of
said overlapping region, said annular die comprising a
plurality of mating die sections hingedly
interconnected to enable insertion of said tubular
20 members and extraction thereof in the open position of
said die sections, said inner surface of said annular
die having a plurality of circumferentially spaced
axially extending recesses and at least one radial
recess extending about said inner surface, said
25 recesses extending radially outwardly so as to enable
said inner surface to contact the outer
circumferential surface of said tubular members;

30 (b) inserting an electrical coil member
which is connected to a source of electrical energy
into said tubular members so as to extend into said

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1 overlapping region within the confines of said annular die;

(c) applying an electrical current to said coil member by said source of electrical energy so as to impart an electromagnetic force to the interior of said tubular members in said overlapping region by said coil member to generate a deformation force expanding said tubular members radially outwardly within said overlapping region so as to impress said pattern of recesses on said inner die surface onto said tubular members to produce a corresponding pattern of axial and radial outwardly expanded grooves therein forming said torque joint; and

(d) opening the hingedly interconnected mating die sections upon completion of the formation of said grooves so as to facilitate extraction of said torque joint from said annular die.

8. A method as claimed in Claim 7, wherein said tubular members are expanded within said overlapping region to an outer diameter of a size substantially that of the diameter of the configuration of the inner cylindrical surface of said annular die.

9. A method as claimed in Claim 7, wherein said annular die includes an annular inwardly extending shoulder at one edge of the inner cylindrical surface, said shoulder limiting axial insertion of said tubular members into said die and forming a reduced diameter area on said tubular members adjacent the grooves formed therein upon

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1 deformation of said tubular members responsive to said
electromagnetic force.

10. A method as claimed in Claim 7, wherein
a plurality of said radial grooves are formed in said
5 tubular members spaced along the length of the formed
axial grooves so as to provide a predetermined pattern
of grooves reacting to axial and torsional loads
imparted to the formed torque joint.

11. A method as claimed in Claim 7, wherein
10 at least one of said tubular members comprises an end
fitting for a torque joint.

12. A method as claimed in Claim 7, wherein
said electromagnetic coil member insertable into said
tubular members has an outer diameter substantially
15 the size of the internal diameter of said tubular
member within said overlapping region.

13. A die structure for fabricating a
torque joint between two tubular members having one
end of one tubular member inserted into an end of the
20 other tubular member to provide an overlapping region
between the tubular members; comprising:

(a) said die structure encompassing the
overlapping region of said tubular members including
an annular die having an inner cylindrical surface
25 facing the outer surface of said overlapping region,
said inner surface of said annular die having a
plurality of circumferentially spaced axially
extending ridges and at least one radial ridge
extending about said inner surface, said annular die
30 comprising a plurality of mating die sections hingedly

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1 interconnected to enable insertion of said tubular
members and extraction thereof in the open position of
said die sections, said ridges projecting radially
inwardly so as to contact the outer circumferential
5 surface of said tubular members in the closed
condition of said mating die sections, and said inner
surface of said die defining an annular space with the
outer circumferential surface of said tubular members;

(b) an electrical coil member which is
10 connected to a source of electrical energy being
inserted into said tubular members so as to extend
into said overlapping region within the confines of
said annular die; and

(c) said coil member having an electrical
15 current applied thereto by said source of electrical
energy for imparting an electromagnetic force to the
interior of said tubular members in said overlapping
region so as to generate a deformation force expanding
said tubular members radially outwardly within said
20 overlapping region so as to impress said pattern of
ridges on said inner die surface onto said tubular
members to produce a corresponding pattern of axial
and radial grooves therein forming said torque joint.

14. A die structure as claimed in Claim 13,
25 wherein said tubular members are expanded within said
overlapping region to an outer diameter of a size
substantially that of the diameter of the inner
cylindrical surface of said annular die.

15. A die structure as claimed in Claim 13,
30 wherein said annular die includes an annular inwardly

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1 extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
forming a reduced diameter area on said tubular
5 members adjacent the grooves formed therein upon
expansion of said tubular members responsive to said
electromagnetic force.

16. A die structure as claimed in Claim 13,
wherein a plurality of said radial grooves are formed
10 in said tubular members spaced along the length of the
formed axial grooves so as to provide a predetermined
pattern of grooves reacting to axial and torsional
loads imparted to the formed torque joint.

17. A die structure as claimed in Claim 13,
15 wherein at least one of said tubular members comprises
an end fitting for a torque joint.

18. A die structure as claimed in Claim 13,
wherein said electromagnetic coil member insertable
into said tubular members has an outer diameter of
20 substantially the size of the internal diameter of
said tubular member within said overlapping region.

19. A die structure for fabricating a
torque joint between two tubular members having one
end of one tubular member inserted into an end of the
25 other tubular member to provide an overlapping region
between the tubular members; comprising:

(a) said die structure encompassing the
overlapping region of said tubular members including
an annular die having an inner cylindrical surface
30 facing the outer surface of said overlapping region,

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1 said inner surface of said annular die having a
plurality of circumferentially spaced axially
extending recesses and at least one radial recess
extending about said inner surface, said annular die
5 comprising a plurality of mating die sections hingedly
interconnected to enable insertion of said tubular
members and extraction thereof in the open position of
said die sections, said recesses extending radially
outwardly so as to enable said inner surface to
10 contact the outer circumferential surface of said
tubular members in the closed condition of said mating
die sections;

(b) an electrical coil member which is
connected to a source of electrical energy being
15 inserted into said tubular members so as to extend
into said overlapping region within the confines of
said annular die; and

(c) said coil member having an electrical
current applied thereto by said source of electrical
20 energy for imparting an electromagnetic force to the
interior of said tubular members in said overlapping
region so as to generate a deformation force expanding
said tubular members radially outwardly within said
overlapping region so as to impress said pattern of
25 recesses on said inner die surface onto said tubular
members to produce a corresponding pattern of axial
and radial outwardly expanded grooves therein forming
said torque joint.

20. A die structure as claimed in Claim 19,
30 wherein said tubular members are expanded within said

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1 overlapping region to an outer diameter of a size
substantially that of the diameter of the
configuration of the inner cylindrical surface of said
annular die.

5 21. A die structure as claimed in Claim 19,
wherein said annular die includes an annular inwardly
extending shoulder at one edge of the inner
cylindrical surface, said shoulder limiting axial
insertion of said tubular members into said die and
10 forming a reduced diameter area on said tubular
members adjacent the grooves formed therein upon
deformation of said tubular members responsive to said
electromagnetic force.

22. A die structure as claimed in Claim 19,
15 wherein a plurality of said radial grooves are formed
in said tubular members spaced along the length of the
formed axial grooves so as to provide a predetermined
pattern of grooves reacting to axial and torsional
loads imparted to the formed torque joint.

20 23. A die structure as claimed in Claim 19,
wherein at least one of said tubular members comprises
an end fitting for a torque joint.

24. A die structure as claimed in Claim 19,
wherein said electromagnetic coil member insertable
25 into said tubular members has an outer diameter
substantially the size of the internal diameter of
said tubular member within said overlapping region.

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AMENDED SHEET (ARTICLE 19)

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FIG. 1

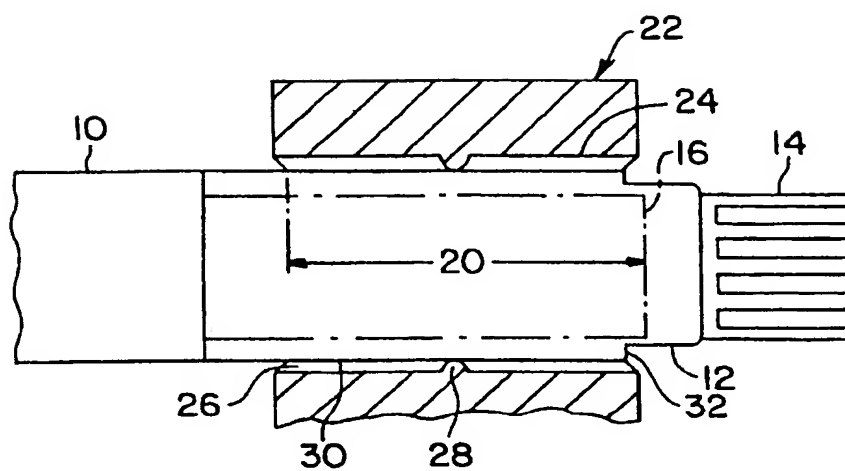
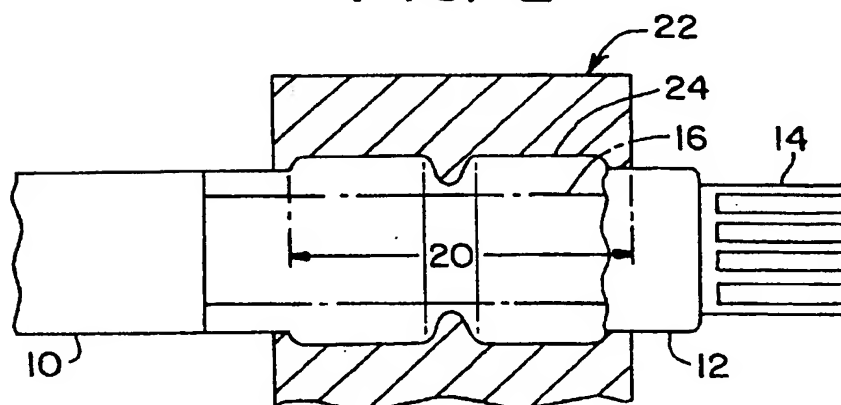
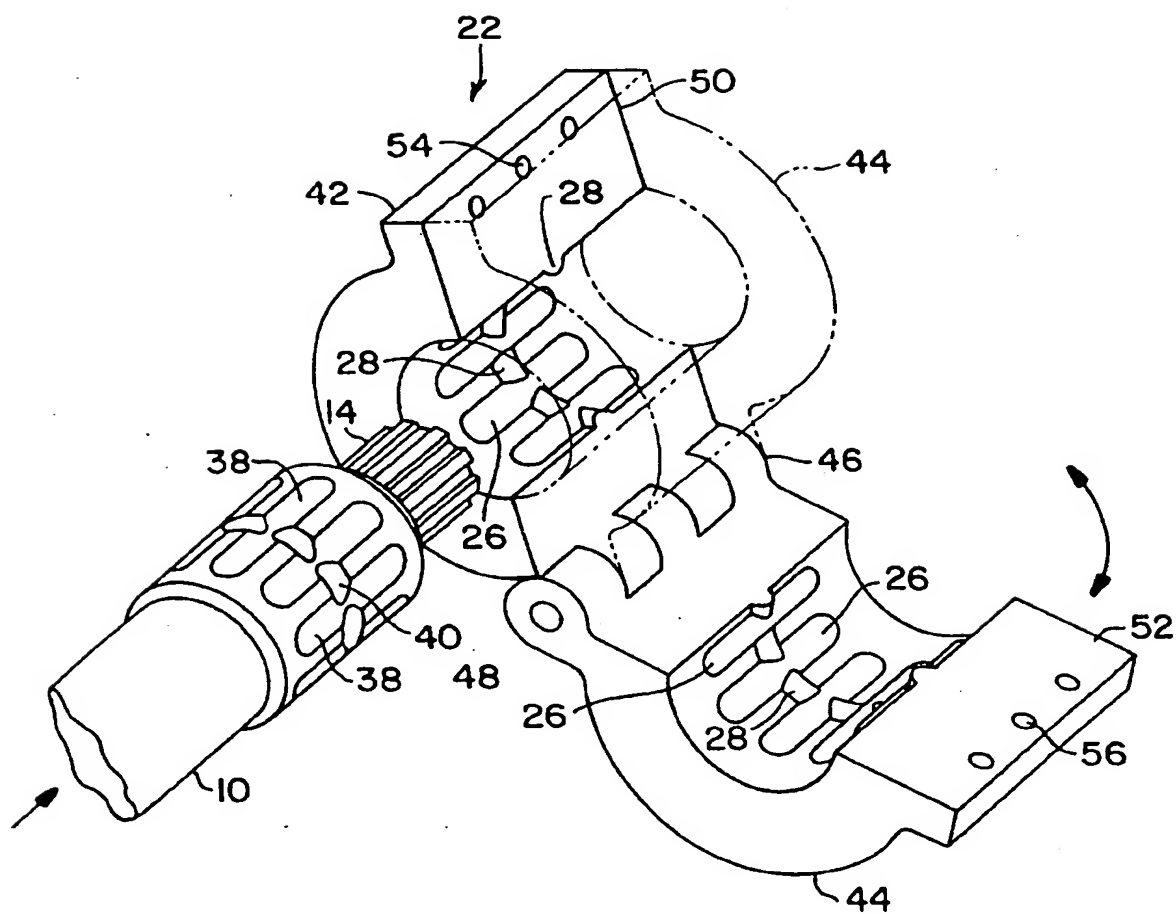


FIG. 2



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FIG. 3



SUBSTITUTE SHEET (RULE 26)

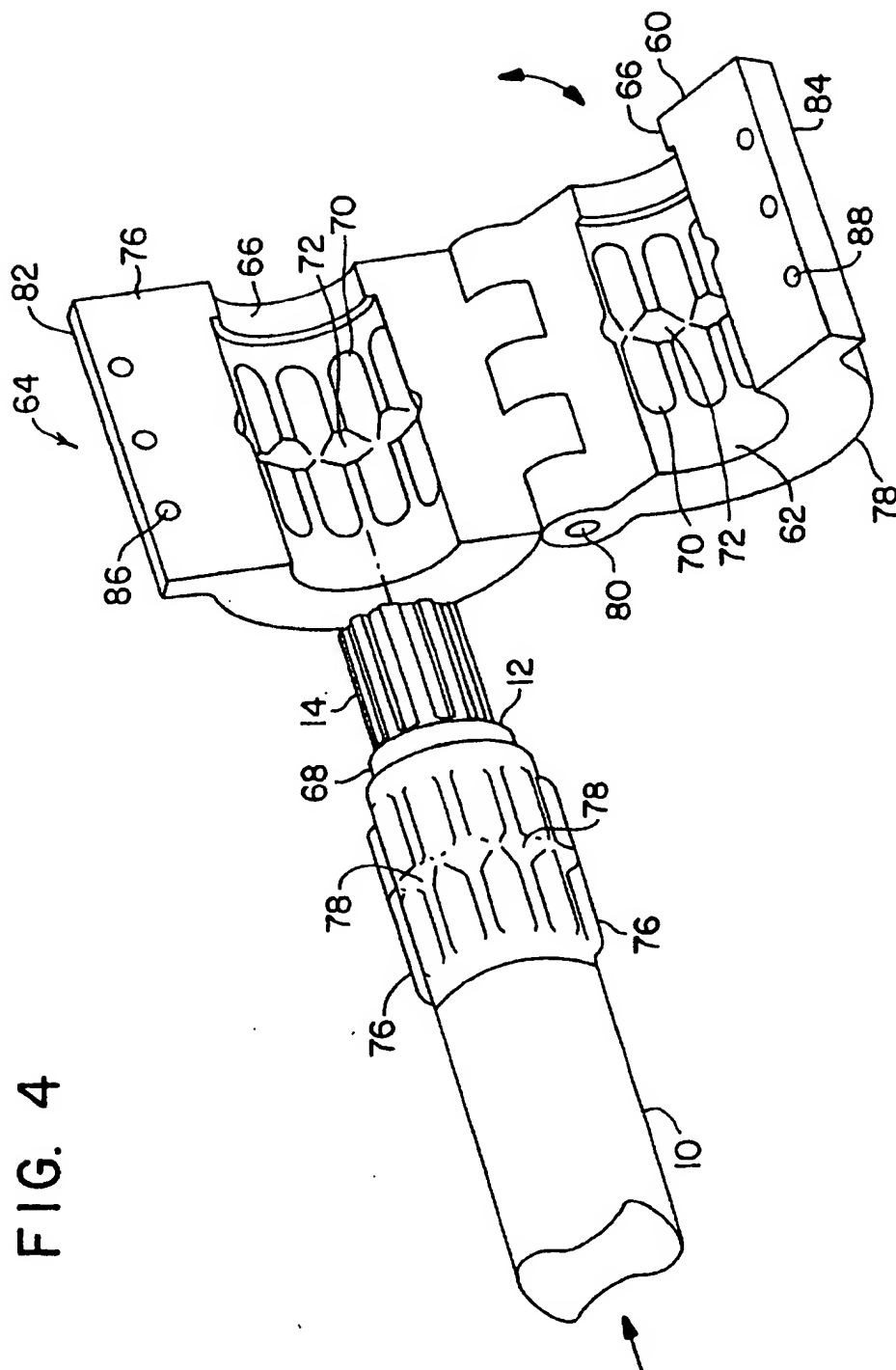


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/08118

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B21D 39/00, 28/18

US CL :29/523; 72/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 29/523, 522.1; 72/62, 61, 370, 707

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,810,372 A (QUEYROIX) 14 May 1974, SEE ENTIRE DOCUMENT	1-17, 19-24 and 26-28
Y	US 4,125,000 A (GROB) 14 November 1978, SEE ENTIRE DOCUMENT	1-17, 19-24 and 26-28



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
B earlier document published on or after the international filing date	Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	A*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

20 AUGUST 1997

Date of mailing of the international search report

09 SEP 1997

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